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PREVENTING AND CORRECTING SPREAD OF MISINFORMATION ABOUT NEOS, IMPACTS, AIRBURSTS, AND PLANETARY DEFENSE: CASE STUDIES

Mark Boslough[1,2], Peter Brown[3], Andy Bruno[4], Paul Chodas[5], Gareth Collins[6], Tyrone Daulton[7], Alan Harris[8], Christian Koeberl[9], Ania Losiak[10], David Morrison[11], Olga Popova[12], Darrel Robertson[13], Elizabeth A. Silber[14], and Matthias van Ginneken[15]

[1]*Los Alamos National Laboratory, Los Alamos, NM, 87545, USA, mbeb@lanl.gov,* [2]*University of New Mexico, Albuquerque, NM, 87131, USA, mbeb@unm.gov,* [3]*University of Western Ontario, Canada* [4] *Indiana University Bloomington, USA* [5]*Jet Propulsion Laboratory, USA* [6]*Imperial College London, UK* [7]*Washington University in St. Louis, USA* [8]*Jet Propulsion Laboratory (retired),USA* [9]*University of Vienna, Austria* [10]*Institute of Geological Sciences, Polish Academy of Sciences, Poland* [11]*NASA (retired), USA* [12]*Institute of Geosphere Dynamics, Russia* [13]*NASA Ames Research Center, USA* [14]*Sandia National Laboratories, USA* [15]*University of Kent, UK*

Abstract

One implicit assumption in our planetary defense tabletop exercises is that, in the real world, the participants will be competent and acting in good faith. Recent history demonstrates that this may not be the case. Attacks on mainstream science and scientists in the context of NEOs, impacts, airbursts, and planetary defense are already underway, but the stakes remain low because there are currently no imminent threats. Our planetary defense community exists because we believe that we should be prepared for the eventual discovery of an object on a certain collision course. It is logical that part of our preparation should anticipate bad actors, propaganda campaigns, denial, and disinformation. This paper reviews examples of misinformation, suggests various means of preventing and correcting its spread, and recommends proactive strategies for addressing it in the context of planetary defense.

Keywords: disinformation, propaganda, denial, clickbait, social media

Introduction

In most of our hypothetical impact scenarios, there will likely be winners and losers. The stakes could be enormous in terms of casualties, economic loss, and geopolitics, and the consequences will not likely be distributed evenly. The black comedy film “Don’t Look Up” was ostensibly about the discovery of a doomsday comet on a collision course with Earth but was clearly an allegory for the current slow-motion climate crisis, collapsed into a much shorter timeframe to provide a better framework for storytelling. One premise of the movie that creates irony is the contrast to an imagined real world, in which leaders and citizens would obviously take the specter of

a catastrophic impact seriously. The capacity for conspiracy thinking, misinformation, and denial calls this assumption into question.

Misinformation associated with our field is already rampant. In many cases, it is driven by clickbait media that are indifferent to the facts but motivated instead by a business model that depends primarily on the revenue stream. Other examples are researchers on the fringes of science who are focused less on facts and more on Altmetric scores (a measure of engagement) and citation counts (e.g. h-index). In the event of a real-world impact emergency, we should anticipate that this noise will get louder, with the potential to drown out factual information provided by experts. We should not assume that members of our community will be immune from personal attacks and defamation campaigns, as professionals in other disciplines (climate science and immunology) have experienced in recent years.

This paper provides case studies of past and current instances of misinformation associated with asteroids, comets, impacts, airbursts, and planetary defense. We examine the origin and spread of misinformation, provide context, suggest methods to limit its propagation and potential damage, and advocate for institutional support by this activity by individual researchers.

Types of Misinformation

We consider several case studies of misinformation to illustrate the wide variation in its origin, motivation, means of propagation, duration, and potential harm. These attributes are not discrete and, in most cases, can be described as a continuum. For example, misinformation can be created innocently (by misunderstandings, misinterpretations, ignorance, or even typographical errors), intentionally (for pranks, attention, clickbait, or malicious propaganda), or by some ill-defined combination, as flawed collective human behavior in which some individuals are acting in good faith and others are not. Intentional and malicious misinformation is often described as “disinformation”.

At the benign end of the spectrum are the oft-repeated myths that the Tunguska explosion “felled an estimated 80 million trees” and that “if the Tunguska object had arrived 4 hours, 47 minutes later, it would have destroyed St. Petersburg”. These relatively harmless myths illustrate the ease by which misinformation can originate and propagate, and the difficulty in correcting them once they have taken hold. Unfortunately, they have also contributed to published conclusions in peer reviewed papers that are not supported by the evidence, and to enduring misunderstandings that have crept into news stories and the scientific literature.

More damaging are myths and misrepresentations associated with orbital mechanics and airburst physics connected to claims that comet explosions wiped out settlements in the middle east and North America, the abrupt climate change at the beginning of the Younger Dryas, and to the misidentification of materials used as evidence for a supposed interstellar bolide. These myths and misunderstandings have been propagated by credentialed scientists and published in nominally peer-revied journals, fueling pseudoscientific claims and animosity toward mainstream science and scientists (including that related to planetary defense).

Deadly misinformation in our field, so far, has been rare. The most notable example was the claim that Comet Hale-Bopp was accompanied by an alien spaceship that would arrive in 1997. This myth led to the ritual mass suicide of 39 members of the Heaven's Gate religious cult, who believed the UFO was arriving to take their souls to another level of existence. Comet co-discoverer Alan Hale, who had anticipated suicides, blamed the "combination of scientific illiteracy, willful delusions, a radio talk show's deception about an imaginary spacecraft following the comet." We cannot know if the suicides could have been prevented with better information, but this event illustrates how powerful misinformation can be, especially with groups whose members reject established science, lack critical thinking skills, distrust the establishment, and embrace alternative, unscientific, or paranormal beliefs.

The time scale of misinformation can span the range from an hour to a century. To be effective, the speed of intervention with accurate information must be commensurate with the speed of developments. The Chelyabinsk airburst of Feb. 15, 2013 is a good example of the need for rapid response, as misunderstandings immediately filled the information vacuum in a way that could have dominated the subsequent narrative without intervention. Misinformation associated with Comet Hale-Bopp emerged more slowly, on the time scale of months, and took hold despite the efforts of scientists to provide accurate information. The Tunguska event of June 30, 1908 has spawned misinformation that has endured for nearly a century, and that continues to be accepted as fact, even by some members of the scientific community. These and other case studies are highlighted in this paper, which are selected to represent various types of misinformation that are relevant to the field of planetary defense.

Short-term and Rapidly Developing Cases

Rapidly developing misinformation requires rapid response, and cases in 2013 and 2014 provided the impetus for the creation of an ad hoc group of scientists and subject matter experts that can provide accurate and timely information within the immediate news cycle, before official institutional statements can be prepared and approved. Case studies include the Chelyabinsk event, The 2000 EM_{26} non-event, the CNN asteroid impact hoax, the unauthorized naming of marginally newsworthy asteroids, and the Nicaragua "impact crater".

<u>Chelyabinsk event and 2012 DA_{14}</u>

Media interviews and press conferences were scheduled for the morning of Feb. 15, 2013 for asteroid and planetary defense experts to provide information about asteroid 2012 DA_{14} (later renamed "367943 Duende"), which was going to pass within 4.3 Earth radii later that day and had become a major news story. At about 9:20 am local time in Chelyabinsk, Russia (03:20 UTC), the brightest bolide in the history of recorded observations unexpectedly appeared. This was 10:20 pm EST and 4:20 CET, the time zones of Washington, DC and Vienna, respectively, where most of the top planetary defense experts and decision makers were living or visiting.

Some of first public notifications to reach the west were social media and specialized websites with links to Russia. At 04:38 UTC, the Russian news service RT posted the article, "Meteorite crash in Russia: UFO fears spark panic in the Urals" It repeated rumors, including, "According to unconfirmed reports, the meteorite was intercepted

by an air defense unit at the Urzhumka settlement near Chelyabinsk," and "The regional Emergency Ministry said the phenomenon was a meteorite shower, but locals have speculated that it was a military fighter jet crash or a missile explosion." The concluding sentence of the article was, "It is believed that the incident may be connected to asteroid 2012 DA14, which measures 45 to 95 meters in diameter and will be passing by Earth tonight at around 19:25 GMT at the record close range of 27,000 kilometers."

The original story was later replaced by RT, using the same URL (http://rt.com/news/meteorite-crash-urals-chelyabinsk-283/), with the rumors and false claim about DA14 removed. But the misinformation cat was already out of the bag and spreading on social media, where it still remains and can be used to confirm the content of the original version of the story. One of the first to see it was a climate scientist in eastern Canada, who was playing midnight online chess with Russians and posted a link to the RT story on Facebook only 14 minutes after it had appeared. One of us (MB) saw is a few minutes later, about 1.5 hours after the asteroid struck the atmosphere. The FB poster wrote, "Must be fragments that once were part of larger chuck of rock passing by on Friday?" MB later replied "There is no reason to think this is related to 2012 DA15" despite the obvious futility of stopping misinformation this way.

After failed attempts to contact Peter Brown and Richard Spalding, MB found another online story, posted on the website of Russian Machine Never Breaks (RMNB), an obscure Washington, DC hockey blog that was the first US source to cover the story It was arguably more professional and cautious than RT with its updated post at 12:24 am (05:24 UTC), in addition to remaining true to its primary mission (hockey):

> **LATE UPDATE**: No immediate confirmed reports of casualties. See the AP for more information. We're getting all kinds of information about explosions in Chelyabinsk, the city in the Ural region of Russia that hosts Evgeny Kuznetsov's KHL team. Information is sparse right now, and we do not want to speculate. (http://www.russianmachineneverbreaks.com/2013/02/14/what-is-happening-in-chelyabinsk/)

MB sent these links to his planetary defense colleagues who lived in the westernmost two US time zones at 10:07 MST (05:07 UTC) with the comment, "This just happened, apparently" under the subject line, "Huge bolide in Russia just now". Clark Chapman was the only one to respond, writing "Clearly we all may be asked about his coming, as it does, very close in time to the passage of DA14."

MB was also able to reach coauthor PC, and together they determined from videos that the bolide entered from the direction of the sun and therefore could not have anything to do with 2012 DA14. PC stated definitively in his last email of the night, that "This fireball can't be associated with DA14 at all." At 1:00 am MST (08:00 UTC) MB forwarded PC's conclusion to a large list of planetary defense experts who might be interviewed by the media the following day and would be able to make the statement "This fireball can't be associated with DA14 at all" with the conviction and confidence on the authority of PC, knowing that those were his words.

This experience suggested the need for a distributed means of communication among planetary defense workers with diversity of expertise, affiliation, nationality, and time zone, so that a sufficient number subject matter experts are always “on call” and can provide facts, opinion, and advice to those who might lack specific expertise or access to information sources, but find themselves on the receiving end of a media request by a journalist on deadline who will simply go to another (possibly less informed) source if the request is delayed or denied.

Media-stoked sensationalism and misinformation in 2014

Several events in 2014 reinforced the need for a distributed, diverse, and rapid means of communication among planetary defense experts. One was the growing realization that stories about asteroids and “near misses” were good clickbait fodder, and the exploitation of relatively insignificant events and objects to get publicity.

On Feb. 17, 2014, to commemorate the first anniversary of Chelyabinsk, a commercial telescope streaming service called Slooh promoted a live stream of the supposed “near miss” of asteroid 2000 EM_{26}. Despite never having heard of this asteroid, MB agreed to participate in the broadcast, which was both a success (it got over a million views) and a flop (the telescope failed to detect the asteroid). Joel Achenbach had just written a story in the Washington Post in which he stated “The clicks don’t count if the story is wrong. .... the ultimate virtue in this business is getting it right.” AW looped him into an email conversation including MB, DM, Clark Chapman, and Kendrick Frazier, and brought up the 2000 EM_{26} affair and the consistently bad reporting that accompanied it. MB described his experience with live stream to the group: “About 5 minutes before airtime I asked what was notable about 2000 EM26. They said that it wasn't particularly noteworthy except for the fact that it was near the anniversary of Chelyabinsk.” Achenbach’s story for the Washington Post broke ranks with all the other media outlets that had hyped the non-event, and was titled, “Asteroid did not nearly hit Earth, Actually”. This example illustrates the value of subject matter experts reaching out to journalists.

On May 26, 2014, CNN iReport reported that a “giant asteroid” was “possibly on a collision course with Earth” with a “1-in-2.04” odd of impact in 2041. iReport was hosted by CNN for unvetted un-fact-checked, unscreened, and unedited articles written by anyone who got an account, but under the CNN logo). This was quickly identified by Bad Astronomy blogger Phil Plait, who notified Amy Mainzer and was able to get a screen shot showing that it had gotten nearly 300,000 views before it was finally removed by CNN after being viewed shared for more than 24 hours. This example illustrates the value of scientists who blog, and are active on social media.

On June 8, 2014, the success of Slooh’s live stream, in terms of clicks, led to the promotion of another “near miss” media event, this time of asteroid 2014 HQ124 which had made a closer, but unseen, pass in 1952. The promoters created the nickname, “The Beast”, which was widely used by news outlets in their quest for clicks. MB participated in the live stream again with a focus on factual information, but the real significance of the event was overlooked by many of the reporters: the high-resolution radar imaging opportunity at Goldstone and Arecibo that resulted in a good quality shape model indicating that it is a contact binary. To its credit, on the day of the close approach, the Arecibo Radar account, tweeted “For the record, we do not use

nicknames to refer to asteroids. Anthropomorphizing nature is confusing and misleading." Nevertheless, Slooh was still nicknaming asteroids as of October, 2015, when it created the moniker "Spooky" (the Halloween Asteroid) for the close approach of 2015 TB145. This example illustrates the value of institutions using social media.

On Sept. 8, 2014, BBC News reported "Meteorite that hit Nicaragua 'dropped off' larger asteroid, quoting an astronomer who speculated that the meteorite was "a bit" that "must have dropped off" the known 2014 RC asteroid. Members of the scientific community immediately rejected this notion, later that day NASA put out a statement titled "Did a Meteorite Cause a Crater in Nicaragua?" casting doubt on that assertion. The statement described the event and concluded, "While a meteoritic origin for this crater cannot be ruled out with absolute certainty, the information available at this time suggests that some other cause is responsible for its creation." Subsequent news stories were consistent with this position. This example illustrates the importance of rapid response to questionable news stories. Further, it illustrates the care that scientists must take when answering questions from the media that may be outside their area of expertise.

Collectively, this series of events over a period of less than two years underscored the need for scientists to participate in behind-the-scenes conversations to provide information and advice to one another. Over the intervening decade, the news cycle has shrunk, along with budgets for professional science journalists, while clickbait incentives have increased. The need for rapid, informed response to unexpected, fast-breaking news has grown commensurately.

Intermediate-term and Peer Reviewed Cases

Younger Dryas Impact Hypothesis (YDIH)

One of the most widely reported developments related to planetary defense over the last 2 decades has been the Younger Dryas impact hypothesis (YDIH). If true, this idea would upend everything we know about the physical and observational basis for impact risk assessment, including NEO populations, impact cratering, and airburst physics. However, most of the assumptions and interpretations by the authors of the YDIH are based on fundamental misunderstandings or rejection of airburst physics, impact diagnostics, shock physics, and orbital mechanics.

The most up-to-date review of the YDIH is by Holliday et al [1], who wrote "evidence and arguments purported to support the YDIH involve flawed methodologies, inappropriate assumptions, questionable conclusions, misstatements of fact, misleading information, unsupported claims, irreproducible observations, logical fallacies, and selected omission of contrary information", but did not address the planetary defense implications. Whereas the YDIH has been embraced by pseudoscientists, conspiracy theorists, and those who deny mainstream science, it is rejected by the vast majority of subject matter experts in all the fields of science that it purports to revolutionize, including planetary science, archaeology, paleoclimatology, paleontology, paleoecology, geochemistry, minerology, and geology.

The authors of the paper that introduced the YDIH to the scientific literature [2] revealed their misunderstanding of the basic physics that controls airbursts in their

attempt to argue that an airburst could affect the entire North American continent. They cited Toon et al [3] in support of the statement that "if airbursts explode with energy of 10^7 megatons at optimum height, they will cause blast damage over an area the size of North America that is equivalent to a ground impact of 10^9 megatons." This misconception was addressed by Boslough et al [4] who wrote:

> *Optimum height of burst is a concept from the nuclear weapons effects literature. It is the prescribed altitude for a point-source explosion to maximize surface damage. According to Glasstone and Dolan [1977], it is "that at which it is estimated a weapon of a specified energy yield will produce a certain desired effect over the maximum possible area." For the YD impact hypothesis, the "desired effect" is damage due to blast wave.*
>
> *When the optimum altitude for creating blast waves (which neglects the Earth's curvature) is extrapolated, a 10^7 Mt explosion must be detonated at 500 km to generate continental-wide effects [Glasstone and Dolan, 1977]. Whereas nuclear weapons can be set off at any altitude, there is no physical mechanism that can cause a comet to explode in outer space (e.g., 500 km). Such an explosion would require the conversion of significant kinetic energy to internal energy for heating and vaporizing the comet. This would necessitate momentum loss through drag on the cometary mass. In the absence of air, there is no mass to which momentum can be transferred, and such an explosion would violate the laws of physics. Therefore, one cannot use the optimum height concept to constrain the mass (and explosive equivalence) of large comets.*

Coauthor DM and Kevin Zahnle, who were both coauthors of Toon et al [3], have rejected the extrapolation by Firestone et al [2]. According to Zahnle (personal communication to MB and DM), "it is nonsense to think of an airburst occurring in a near vacuum above 500 km altitude (what geometry suggests would be needed if one seeks continental damage)… Beyond that, how is one to imagine an impacting body – say 200 m diameter, which maps to 100 Mton – being aerobraked at 100 km or whatever it would be? We certainly neither said nor implied anything of the ... Quite the opposite." Nevertheless, after nearly 2 decades this misunderstanding by Firestone et al [2] continues to be used as support for one of the primary YDIH claims of continent-wide devastation

YDIH proponents have also created their own ambiguous terms, such as "meltglass", "scoria-like objects" (SLOs), "impact proxies", and "shock-fractured quartz" in stark contrast to the kind of detailed technical definitions that have applied by mainstream impact scientists to widely understood and scientifically accepted terms such as diaplectic, glass, maskelynite, tektites, lechatelierite, impact diagnostics, and shocked quartz.

These YDIH-related misunderstandings and ambiguously defined evidence have recently spawned "spin-off" hypotheses involving the destruction of several ancient human settlements.

<u>Airburst Destruction of Ancient Human Settlements</u>

In 2012, two archaeologists discovered what they interpreted as evidence for the destruction of an ancient village in Syria called Abu Hureyra, which was excavated in the 1970s and is now at the bottom of Lake Assad, the reservoir that was created when the Euphrates River was dammed [5]. Their hypothesis was inspired by the YDIH, one author (DK) having been a coauthor of the seminal paper [2]. The Abu Hureyra authors repeated the YDIH misunderstandings and added to them, invoking, "a large comet or asteroid up to several kilometers in size fragmenting in the Earth's atmosphere" that "resulted in multiple airbursts and small direct impacts with the Earth's surface."

The authors further asserted that "the geographic extent of the ejecta is comparable in size to the Australasian field that is accepted as resulting from a large fragmented comet." This is presumably a reference to the Australasian strewn field, which is associated with tektites from a single impact in SE Asia and has nothing to do with a fragmented comet. They described, but did not explain the orbital mechanics, of how this could be associated with a comet explosion over North America, "The evidence suggests that the asteroid or comet passed through the northern hemisphere c. 12,900 cal. BP, breaking up and causing a series of airbursts and impacts on the way… In an extraordinary coincidence, one of the impacts/airbursts occurred in the vicinity of Abu Hureyra, destroying the site and many of its inhabitants."

They teamed up with other authors of the YDIH papers to publish a more detailed account [6], in which they stated without evidence that, "The largest cometary debris clusters are proposed to be capable of causing thousands of airbursts within a span of minutes across one entire hemisphere of Earth. An encounter with such a million-km-wide debris cluster would be thousands of times more probable than a collision with a 100-km-wide comet or a 10-km asteroid. The YDB hypothesis proposes this mechanism to account for the impact at Abu Hureyra and coeval impacts across >14,000 km of the Northern and Southern Hemispheres." The idea of a broken comment creating a debris cluster suggests that the YDIH authors do not appreciate a fact that is widely understood in the planetary defense community. Small velocity perturbations of objects in heliocentric orbits ten dto spread them out along the direction of motion that would lead to a narrow impact corridor and could not create a large area akin to the Australasion strewnfield which is defined by tektites that reentered on ballistic trajectories that were ejected in all directions from a single source location on Earth's surface.

Two other papers by the YDIH authors with the same misunderstandings of airburst physics and orbital mechanics, who used similar evidence and arguments to conclude that other human settlements were also destroyed by airbursts (Tall el-Hammam in Jordan, and Hopewell in Ohio) were published in quick succession in 2021 and 2022, respectively. Both have been retracted by Scientific Reports because the evidence they presented did not support their conclusions [7-10].

Long-Term, Enduring, and Self-Perpetuating Cases

The 1908 Tunguska airburst has contributed greatly to our understanding of impact hazards. It has also spawned more than a century of myth and misinformation, some of which has even taken root within the scientific community. Many falsehoods about Tunguska have innocent origins and are simple misunderstandings that have become

"factoids" through repetition. Others appear to be manufactured disinformation intended to bolster clickbait, discredit mainstream science, and/or support pseudoscience. Here are a few examples.

If the Tunguska object had arrived 4 hours, 47 minutes later, it would have destroyed St. Petersburg**.** False. This assumes a geocentric orbit in which only Earth's rotation matters. In reality, Earth's motion around the sun would have caused it to miss by a half million km.

The "Tunguska crater" image**.** Internet stories about Tunguska often use a photograph of a circular feature, implying that it was created by the event. It was not. We have learned that it is a clearing at (58°13'53.0"N, 100°15'32.4"E), about 300 km south of the Tunguska epicenter, called "Devil's Cemetery". Searches on the local name "чертово кладбище" reveal that it is widely associated with Russian conspiracy theories and pseudoscientific speculation.

The Tunguska event "toppled or *snapped* > *80 million trees*". Boslough & Bruno [10] showed that this myth was boosted by Brazo and Austin [11] which was not peer reviewed and is not a reliable source of information about science. It appeared in the journal *Origins*, a publication of the Institute for Creation Research (ICR), which professes young-Earth creationism. *Origins* masquerades as a scientific journal and publishes papers used to support claims by biblical catastrophists whose aim is to exaggerate the rate, timing, and magnitude of geological events in support of ICR beliefs.

The "> *80 million trees*" statement is an exaggeration of pre-existing misinformation. Brazo and Austion [11] wrote "eighty million trees in the taiga (coniferous forest) were uprooted and blown down". They cited Whipple [12] who, in fact, didn't make any claims about 80 million trees. He had quoted a correspondent who appears to have been referring to article by Crommelin [13], who wrote, "The overthrown trees cover an area of 8,000 square kilometers, and number about 80 million," citing an obscure Russian-language paper by Astapovich [14]. The original purpose was to make a "back of the envelope" estimate of the explosion's energy, using rough estimates of the tree fall area to make an educated guess of the number of fallen trees. Astapovich wrote, "Apparently, it can be assumed that the area of the fallen forest occupies about 8000 km^2" to reach his estimate, "the work of the windfall of 8.10^7 trees would be $4.4.10^{21}$ ergs".

Unfortunately, Crommelin [13] misrepresented Astapovich's educated guesses as facts. Brazo and Austin [11] exacerbated the myth by misattributing Crommelin's numbers to Whipple [12] and also neglected to determine that the original source was based on a preliminary guess of the area of devastation that turned out to be about ¼ the actual size. The authors of the retracied Tall el-Hammam paper were not the first to be fooled by Brazo & Austin [11]. Since their paper was published, the false "80 million trees" claim has been repeated in other peer-reviewed papers and has propagated into other sources including Wikipedia.

The fallen trees at Tunguska were "up to 1-m in diameter". Boslough & Bruno [10] showed that this is another myth created by Brazo and Austin [11] and exaggerated by the authors of the retracted Tall el-Hammam airburst paper. This is an example of

“creeping exaggeration” by authors who have failed to get the latest information from modern, authoritative sources. The quoted size of the largest trees that were toppled by the Tunguska airburst has increased through progressive embellishments and selective citation by authors who neglected to read the appropriate primary literature.

The first researcher to reach in the Tunguska blast zone was Leonid Kulick who documented his first impressions, writing "десяти-двадцативершковых великанов." This can be rendered "ten-to-twenty *vershok* giants." A *vershok* is an obsolete unit of length that was equal to about 4.4 cm in 1927. Kulik’s preliminary guess of the diameter of the largest ranged from 44 to 88 cm. Subsequent surveys have shown that the largest trees were close to the lower end of Kulik’s eyeball estimate. Fast et al, [15], created a table of diameters for the downed trees at Tunguska, in which the largest category were those that are “over 30 cm” wide. Brazo and Austin [11] focused only on Kulik’s obsolete higher estimate but added another few cm for good measure, stating, “He [Kulik] saw an area where trees up to three feet [91.4 cm] in diameter had snapped like toothpicks…” The Tall el-Hammam authors padded the upper estimate by several more cm claiming that some trees were “up to 1-m [100 cm]” across. The volume of a tree can be approximately scaled by the cube of its diameter. The largest tree size, in terms of mass, was therefore inflated by the Tall el-Hammam authors by an order of magnitude, in addition to their exaggeration of the number of trees by a factor of about four.

Conclusions and Recommendations

The rapid expansion of social media, blogs, podcasts, digital video influencers, and other online sources continues to displace traditional and professional news information media at an accelerating pace and has incentivized “clickbait” and poorly fact-checked stories that masquerade as news and documentaries. The increase in open access and predatory journals, coupled with pressure on researchers to publish, has eroded the quality of scientific literature and incentivized rapid publication of papers with inadequate peer review by subject matter experts. These changes have led to an increase in the quantity of misinformation in all fields. Planetary defense is no exception, and the nature of our area of expertise already involves sensational and catastrophic events that are already newsworthy without embellishment.

Misinformation can take many forms and can emerge, propagate, and dominate on time scales that are short relative to the news cycle, which is now less that one day. It can also take place on time scales associated with the scientific publication and academic news release cycle, which is shrinking to months because of the emergence of rapid open-source publishing. It can also arise and endure on time scales of years, decades, or even a century, due to careless citation and repetition of “sticky” but wrong claims.

Prevention and correction of misinformation on each of these time scales requires different methods. The shortest time scale, associated with the news cycle, requires immediate action by subject matter experts around the world. We are not all experts in every sub discipline associated with planetary defense, so when we are called by a journalist on a tight deadline, we are unlikely to be able to answer all the questions as experts. Nevertheless, we all know who can provide accurate answers to those

questions, so it is important to maintain a network of professionals who can rapidly respond when news is breaking. Such a network should not be thought of as a replacement for official statements from organizations, but because it is a distributed and collective system, it can respond much faster than the news cycle. Official statements, which are likely to come later (because they are based on the opinions of the same subject matter experts) serve to cement the same information, in the eyes of the journalists and the public.

Prevention and correction of misinformation on the publication time scale requires a longer, sustained effort that includes publication of comments to journals and post-publication review using PubPeer. Responses to the misinformation associated with the Younger Dryas impact hypothesis have led to the creation of scores of PubPeer pages (cite Table 2) and many published comments (list).

Prevention and correction of “folk facts”, or misinformation that has been culturally embedded for years or decades, is the most difficult and most likely to be met with resistance. In this case, powerful information technology is on our side, because it enables us to check citation chains back to their source more easily than old fashioned physical libraries ever could.

Prevention and correction of misinformation associated with planetary defense requires diligence, patience, and cooperation among scientists, journalists, publishers, and program managers. It is a time-consuming task, but it is essential for maintaining scientific integrity and the trust of the public and decision makers that depend on experts to provide factual information in their interest.

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